

Design and Specifications for
A Concrete Impounding Dam

F. J. Flanagan
T. S. Ford

1906

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DESIGN AND SPECIFICATIONS

FOR

A CONCRETE IMPOUNDING DAM.

A thesis presented by

Francis Joseph Managan

and

Jenney Shepard Ford

to the

President and Faculty

of the

ARMOUR INSTITUTE OF TECHNOLOGY

for the degree of

Bachelor of Science in Civil Engineering,

having completed the prescribed course in

Civil Engineering

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Prof. of Eng Studies
Prof. Civil Engineering

DESIGN AND CONSTRUCTION

FOR

A CONCRETE FOUNDATION DAM.

A thesis presented by

James M. Smith

and

James M. Smith

to the

President and Faculty

of the

ARMY INSTITUTE OF TECHNOLOGY

for the degree of

Bachelor of Science in Civil Engineering.

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Civil Engineering

Chicago

May 15, 1906.

The Directors of the Glendale Improvement Co.,
Chicago,

Gentlemen,

We hand you herewith for your approval the preliminary plans and specifications for your proposed impounding dam and reservoir at Glencoe, Ill., together with the approximate quantities of the various classes of work to be done , which may be used as a basis for bids or proposals. We also submit a brief discussion of the design and the principal reasons for our choice of methods in such cases as were left to our discretion.

To the best of our judgement these plans call for as economical a construction as is consistent with the requirements of this particular case and with reliable engineering practice.

Trusting that thus far the work has been done to your satisfaction, we remain

Yours very truly,

Flanagan & Ford.

MASONRY IMPOUNDING DAM AT GLENCOE, ILL.,
FOR THE GLENDALE IMPROVEMENT CO., OF CHICAGO.

After making a fairly accurate survey of the valley to be submerged by the proposed impounding of the waters of the North Ravine and of the ground adjacent to it within the possible limits of a site for the dam, the site chosen was selected for the following reasons: first, the valley at that point is narrow; second, the site is below all important water-carrying branches but, at the same time is above the abrupt decline of the banks near the mouth and so will give the maximum capacity to the reservoir; third, there is an abrupt bend in the valley just above the site and a small gully which enters just below, and these considered together form an unusually good place for a spillway entirely separate from the dam itself.

This selection carries with it the following data as to dimensions and elevations, which form the working basis of the design, viz. elevation of bed of stream - 58.0 ft; elevation of top - 155.0 ft; water level - 150.0 ft; width of valley on the 155 ft. level - about 385 ft; elevation of surface of hard shale - approximately 125 ft. and above that from 10 to 15 ft. of softer shale and clay with a covering of black soil to the surface. A fair estimate computed from the contour map, places the amount to be stored behind the dam up to the level given above, at approximately 700,000,000 gallons. All the elevations used are relative to a bench at the point where Sheridan Road turns to the west some distance south of the dam. The assumed elevation of this bench is 200 ft.

The undoubted superiority of concrete in modern construction together with the absence of any suitable building stone for long distances from the site in all directions, made the choice of

concrete as the material for the construction of the dam and spillway almost imperative. Its economy, its ease of handling, its more certain homogeneity, and its better resistance to the seepage of water are the strong points in its favor, although others might be mentioned.

The section of the dam itself was designed according to the principles laid down in Mr. Wegman's volume on masonry dam construction, and by the application of his formulas in so far as they fitted this case. (See note at the end of this article as to the authorities consulted.) These principles are: first, that the structure must be safe against overturning; second, that it must be safe against sliding; and third, that it must be safe against crushing; and that all these must apply at any section of the dam from the top down. He finds however, that almost without exception, the second requirement is covered by the application of the other two in any actual case and therefore uses only the first and third in deducing his formulas. The first condition he considers to be governed by the application of the so called theory of the middle third according to which, by restricting the position of the lines of resultant pressure at any section to the middle one-third of that section, all tension at the outer edges of that section is prevented, provided the section be considered rigid and be uniformly loaded. There is at present some question, especially in connection with the use of concrete, as to the economic value of this principle of design, but we have as yet seen no working formula to take its place. The third requirement depends, of course, upon the value of the crushing strength of the material to be used, and will therefore have a widely varying effect on the design according as that quality may be high or low in value. In this case, as will be seen later, the strength is so high as to make the requirement unnecessary.

Following this method as outlined, the procedure in making the accompanying calculations is as follows: a top width of 10 ft. or 9 ft. between copings, is assumed as sufficient for all foot traffic and for the small amount of carriage traffic which may possibly cross the valley by this means. The faces are then continued down vertically until a point is found where this width no longer satisfies the first requirement, or in other words, where the line of resultant pressures falls on the boundary of the middle third. (The line of pressures for reservoir empty is of course in the center at this point.) As this section comes about 15 ft. from the top, the next is taken at 30 ft. below the top , then every 10 ft. to 50ft., and from there every 20 ft. to the bottom; and at each of these sections the formula is so applied as to satisfy the first requirement. According to this method the use of the third requirement is necessary only when it is found by trial that the limit of resistance to crushing is being reached, thus making this the governing factor and making necessary the application of different formulas. Ordinarily this occurs first on the back of the dam and later on the front in the neighborhood of from 75 to 100 ft., below the top for masonry with a crushing strength of about 150 lbs. per square inch, but in the case in hand, the much greater values of the crushing strength of concrete --from 250 to 400 lbs. per sq. in. -- made it possible to omit this third requirement altogether since the lowest section of the dam is considerably above the point where the new formula would begin to be necessary.

At a depth of about 90 ft. the line of pressures for the reservoir empty is found to diverge from the back face of the dam less than does the boundary of the middle third so that a slight increase of width on the back is necessary in order to satisfy the first requirement at that point. This condition is due to the

Following this method as outlined, the procedure in determining the accompanying calculations is as follows: a top width of 10 ft. or 9 ft. between corners, is assumed as sufficient for all local traffic and for the small amount of carriage traffic which may possibly cross the valley by this means. The faces are then continued down vertically until a point is found where this width no longer satisfies the first requirement, or in other words, where the line of resultant pressures falls on the boundary of the middle third. The line of pressures for reservoirs is of course in the center at this point. At this section comes about 15 ft. from the top, the next is taken at 30 ft. below the top, then every 10 ft. to 50 ft., and from there every 20 ft. to the bottom, and at each of these sections the formulae are applied as to satisfy the first requirement. According to this method the use of the third requirement is necessary only when it is found by trial that the limit of resistance to crushing is being reached, thus making this the governing factor and making necessary the application of the present formulae. Ordinarily this occurs first on the back of the dam and later on the front in the neighborhood of from 75 to 100 ft. below the top for reservoirs with a cresting strength of about 150 lbs. per square foot, but in the case in hand, the much greater values of the crushing strength of concrete - from 250 to 400 lbs. per sq. ft. - made it possible to omit this third requirement altogether since the lowest section of the dam is considerably above the point where the new formula would begin to be necessary.

At a depth of about 90 ft. the line of pressures for the reservoir empty is found to divide the back face of the dam less than does the boundary of the middle third so that a slight increase of width on the face is necessary in order to satisfy the first requirement at that point. This condition is due to the

departure of the section at the top from the theoretical triangular shape and is provided for by the batter of 1 in 10 beginning at a depth of 80 ft. and continuing from there to the bottom.

The bottom of the concrete in general is to be let into the rock a distance of from 5 ft. at the maximum section to about 2 ft. at the minimum section, but two extensions, trapezoidal in section, will be sunk as shown in the plans, to a varying depth of not more than five feet below the bottom. Upon reaching the surface of the shale, the section as computed for that point will be somewhat reduced and continued for a distance into the earth, the excavation in which will be carefully refilled in layers to provide resistance against seepage.

Not far from the center of the dam at elevation 70.0 , is located the 20 inch outlet pipe. This position allows something over 10 ft. below the pipe to the bottom which is thought to be ample provision for silting of the bottom. The outlet is controlled by a Rensselaer high pressure valve at each end of the pipe. The lower valve is to be placed in a concrete gate chamber which is to be built in one piece with the dam and upon the top of which is to be placed the valve wheel. The upper valve will be protected by an iron cage or grating built into the dam and the rock at that point, and will be controlled by a valve wheel in a gate house at the top of the dam. This house will be a room of concrete supported on reinforced concrete brackets and situated directly over the valve. The valve stem will be of two inch wrought pipe, supported by iron guides built into the concrete about 12 ft. apart vertically. The water level at any time will be indicated to the attendant by a series of distinctive iron shapes marking the ten-foot, foot, and tenth-foot points.

departure of the section is the top from the theoretical trial water surface and is provided for by the latter of 1 to 10 depending on a depth of 80 ft. and continuing from there to the bottom.

The bottom of the concrete is generally as shown for into the rock a distance of 1 to 5 ft. at the existing section to about 2 ft. at the minimum section, but two extensions, trapezoidal in section, will be shown as shown in the plans, to a varying depth of not more than five feet below the bottom. These extensions the surface of the shale, the section is occupied by that point will be somewhat

reduced and continue for a distance into the earth, the excavation in which will be carefully retained in layers to provide resistance against seepage.

Not far from the center of the dam at elevation 70.0, is located the 20 inch outlet pipe. This position allows somewhat over 10 ft. below the pipe to the bottom which is thought to be ample provision for lifting of the bottom. The outlet is controlled by a Reissner with pressure valve at each end of the pipe. The lower valve is to be placed in a concrete gate chamber which is to be built in one place with the dam and above the top of which is to be placed the valve wheel. The upper valve will be protected by iron cage or grating built over the dam and the top of that cage and will be controlled by a valve wheel in a gate house at the top of the dam. This house will be a room of concrete supported on reinforced concrete piers and situated directly over the gate. The valve stem will be of two inch wrought iron, supported by the guided built into the concrete about 12 ft. above the outlet. The water level at any time will be indicated to the attendant by a series of distinctive iron angles marking the ten-foot, foot, and tooth-foot points.

The plan for the diversion of the stream during the construction, is to build a temporary dam about 30 or 40 feet high at a distance of from 2000 to 3000 feet upstream from the main dam and from there to convey the overflow at El. 145 in an earth channel or a timber flume along the slope of the valley to the entrance of the spillway channel at a distance of about 1000 feet above the dam and around a bend in the valley. This spillway channel will be excavated at once as it is to remain permanently, but it will be used as a part of the diversion channel until after the completion of the main dam, when the outlet pipe will be opened and the water turned in behind the main dam so that the excavation at the spillway site can be carried down to rock. The method of disposing of the overflow during construction is purposely left in this indefinite manner as it is the intention to submit the general scheme to bidders for estimates on their own plans for temporary work and to allow such work to be carried out subject merely to the general supervision of the Engineer.

The spillway channel will begin at El. 145 as mentioned above and will end at El. 135 in the small gully which empties into the main valley below the dam. The spillway itself will be founded on rock about 2.5 ft. below the surface of the latter, and the down stream face will be carried up in steps to El. 150. Its clear waterway over the masonry will be about 50 ft., and the bottom of the channel at El. 145 and to the end will be 25 ft. The excavation around the completed masonry is to be refilled with rammed earth up to El. 145 behind the spillway and El. 142 in front, above which broken rock and boulders ranging up to one-half ton in weight will be packed in up to El. 146 behind the spillway and El. 145 in front. The sides of the channel are to slope at 1-1/2 to 1 and for

The plan for the diversion of the stream during the construction, is to build a temporary dam about 30 x 40 feet high at a distance of from 2000 to 3000 feet upstream from the main dam and from there to convey the overflow at El. 115 to an earth channel at a higher level along the slope of the ridge to the entrance of the railway channel at a distance of about 1000 feet and the dam and ground a bank is to be left. This railway channel will be excavated at once as it is to remain permanent, but it will be used as a part of the diversion channel until after the completion of the main dam, when the outlet flow will be closed and the water turned in behind the main dam so that the excavation at the railway site can be started down to rock. The section of the channel of the railway during construction is as follows: that is that excavation channel as it is the intention to build the general channel to divert the overflow on their own side for temporary work and allow such work to be carried out and a high level in the general supervision of the Engineer.

The railway channel will be at El. 125 as mentioned above and will end at El. 135 in the area where the water enters into the main channel below the dam. The railway channel will be founded on rock about 2.5 ft. below the surface of the level and the concrete channel face will be finished at about El. 120. The water will flow over the dam crest at about El. 125 and the bottom of the channel at El. 115 to be at El. 120. The outlet from the channel will be at El. 115 behind the railway and El. 115 in front, which will be on rock and boulders resting on a gravel bed to which will be added from El. 120 behind the dam and El. 120 in front. The sides of the channel are to be at El. 115 in front.

a short distance above the spillway, and below for a distance of 50 ft., they will be protected from the wash of the overflow by heavy rip-rap.

The accompanying estimates include only the quantities of the various classes of work to be done on the sites of the main dam and of the spillway and channel. The excavation and refill are estimated separately and each in full, but it is to be understood that much of the excavated material will be available for refill and that this fact should materially influence the bids on the latter class of work

is shown in figure above the soil level, and below for a distance of 50 ft., and will be protected from the wash of the overlying heavy strata.

The second series of estimates include only the quantities of the various classes of work to be done on the site of the dam, and of the activity and material. The excavation and refilling of estimated separately and each is tallied, but it is to be understood that much of the excavated material will be available for refilling and that this fact should materially influence the kind of the latter class of work.

COMPUTATION OF PROFILE WIDTHS.

Notation used. All lengths in feet.

P is line of pressures, reservoir full

P' is line of pressures, reservoir empty

Unit of weight is 1 cu. ft. of masonry

a = top width of section

x = unknown width of any joint

l = known width of joint above x

h = thickness of course

n = distance of P' from back edge of x

u = distance of P from front edge of x

m = distance of P' from back edge of l

v = distance between P and P' on x

d = depth of water at x

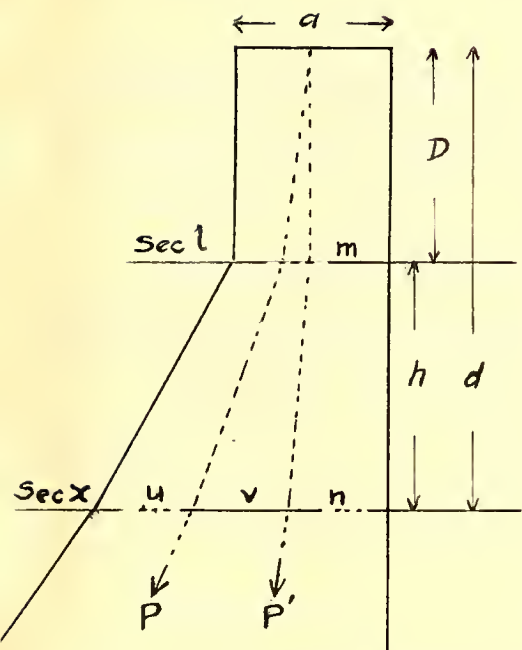
$H = \frac{d}{2r}$ = horizontal thrust of water

$M = \frac{d}{6r}$ = moment of H about any point on x

W = weight of masonry above joint x

w = weight of masonry above joint l

r = specific gravity of concrete



Assumed data.

Maximum height of dam	100 ft.
Width of top	10 ft.
Weight of concrete per cubic foot	130 lbs.
Specific gravity of concrete, r	2.08
Maximum pressure per square inch	250 lbs.
Maximum pressure per square foot in units of masonry	277
Water assumed to top of dam.	

General formula is $x^2 + \left(\frac{4w}{h} + l\right)x = \frac{6}{h}(wm + M) + l^2$ (1)

also $x = u + v + n$ (2) & $v = \frac{M}{W}$ (3)

Notation used. All lengths in feet.

h is line of pressures, reservoir full
 h' is line of pressures, reservoir empty
 Unit of weight is 1 cu. ft. of masonry
 a is width of section
 b is width of any joint
 c is width of joint above
 d is base of course
 e is distance of pivot point edge of
 f is distance of a from front edge of
 g is distance of h from back edge of
 h is distance between h and h' on x
 i is depth of water at x
 J is horizontal thrust of water
 M is moment of H about any point on x
 W is weight of masonry above joint x
 w is weight of masonry above joint x
 γ is specific gravity of concrete

Assumed data.

10 ft.	Maximum height of dam
10 ft.	Width of top
10 ft.	Height of concrete per cubic foot
2.5	Specific gravity of concrete
25 lbs.	Maximum pressure per square inch
	Maximum pressure per cubic foot of water
277	Weight of water
	Water assumed to top of dam

General formula is $x = \left(\frac{W}{\gamma} \right) \left(\frac{1}{a} - \frac{1}{b} \right)$
 $x = \frac{W}{\gamma} \left(\frac{1}{a} - \frac{1}{b} \right)$

Substituting in equation (2) the value of v in (3),

we have
$$x = u + \frac{M}{w + \left(\frac{l+x}{2}\right) h} + n$$

from which we can find h , the depth of the rectangular section at the top by using the following known values:

$$x=l=a; \quad u=\frac{a}{3}; \quad n=\frac{a}{2}; \quad h=d; \quad w=0$$

The reduction of this gives $h=a\sqrt{r}$

which with the given values of a and r gives $h=10\sqrt{2.08}=14.4$

Assuming $h=14$ ft., the next convenient section will be at 30 ft. from the top. The proper values used in equation (1) give

$$x^2 + \left(\frac{560}{16} + 10\right)x = \frac{6}{16}(140 \times 5 + 2161) + 100$$

from which $x=19$ ft.

To find n or the position of P' we use the method of moments and, assuming a center of moments 20 ft. back of the dam, we have,

weight	lever	moment
140	25	3500
160	25	4000
<u>72</u>	<u>33</u>	<u>2376</u>
372	26.6	9876

where 26.6 is the resultant distance to the center of gravity of the weight W .

From this $n=6.6$ ft.

and by equation (3) $v=5.8$

whence $u=19-(6.6+5.8)=6.6$

By the same processes when $d=40$, we obtain

$$x^2 + \left(\frac{372 \times 4}{10} + 19\right)x = \frac{6}{10}(372 \times 6.6 + 5120) + 361 \quad \text{whence } x=25.5$$

Substituting in equation (2) the value of $x = 14.4$.

we have

$$x = 14.4 + \frac{1}{2} \left(\frac{1}{2} + \frac{1}{2} \right) = 14.4$$

from which we can find h , the depth of the rectangular section at the top by using the following known values:

$$x = 14.4; \quad u = \frac{1}{2}; \quad n = \frac{3}{2}; \quad h = 14.4; \quad w = 0$$

The reduction of this gives

$$h = 10.30 \text{ ft.} \quad \text{which with the given values of } x \text{ and } y \text{ gives } h = 10.30 \text{ ft.}$$

Assuming $h = 14.4$ ft., the next convenient section will be at 10 ft. from the top. The proper values used in equation (1) give

$$x = 14.4 + \frac{1}{2} \left(\frac{1}{2} + \frac{1}{2} \right) = 14.4$$

from which

To find h or the position of h , we use the method of moments and, assuming a center of gravity 20 ft. back of the dam, we have,

weight	layer	moment
140	25	3500
160	25	4000
175	25	3875
370	20.5	7585

where 20.5 is the resultant distance to the center of gravity of the weight W .

From this

and by equation (3)

$$h = 10.30 \text{ ft.} \quad \text{where}$$

By the same process when $h = 40$, we obtain

$$x = 14.4 + \frac{1}{2} \left(\frac{1}{2} + \frac{1}{2} \right) = 14.4$$

To find n we take moments as before,

weight	lever	moment
372		9876
190	29.5	5605
<u>32.5</u>	<u>41.5</u>	<u>1339</u>
594.5	28.32	16820

which gives $n=8.30$ $v=8.52$ and $u=8.7$

For a section at $d=50$ we have,

$$x^2 + \left(\frac{4 \times 594.5}{10} + 25.5 \right) x = \frac{6}{10} (594.5 \times 8.30 + 10016) + 650$$

whence $x=32.5$

for which the moments are:

594.5		16820
255	32.75	8351
<u>35</u>	<u>47.83</u>	<u>1674</u>
884.5	30.4	26845

and $n=10.4$ $v=11.30$ $u=10.80$

In the same way at $d=70$

$$x^2 + \left(\frac{4 \times 884.5}{10} + 32.5 \right) x = \frac{6}{10} (884.5 \times 10.4 + 27484) + 1056$$

giving $x=47.0$

and the following moments:

884.5		26845
650	36.25	23562
<u>145</u>	<u>57.33</u>	<u>8312</u>
1679.5	34.9	58719

making $n=14.9$ $v=16.25$ $u=15.85$

To find n we take moments as before.

weight	lever	moment
375		975
190	22.5	4275
35.5	41.5	14732.5
294.5	28.3	8335.35
which gives $n=8.30$ and $n=8.7$		

for a section at $d=50$ we have.

$$x + \frac{1}{2} \times \frac{375 \times 375}{2} + \frac{1}{2} \times \frac{190 \times 22.5^2}{2} + \frac{1}{2} \times \frac{35.5 \times 41.5^2}{2} = 0$$

whence
for which the moments are

294.5	37.5	10927.5
35	41.5	15032.5
284.5	30.4	8648.8
and $n=10.4$ and $n=11.30$ and $n=10.80$		

In the same way at $d=70$

$$x + \frac{1}{2} \times \frac{375 \times 375}{2} + \frac{1}{2} \times \frac{190 \times 22.5^2}{2} + \frac{1}{2} \times \frac{35.5 \times 41.5^2}{2} = 0$$

giving
and the following moments

284.5	37.5	10927.5
35	41.5	15032.5
284.5	30.4	8648.8
making $n=11.0$ and $n=11.5$ and $n=11.30$		

For section $d=90$, we obtain

from which $x=61.5$

and the moments are:

1679.5		58719
940	43.5	40890
145	<u>71.83</u>	<u>10271</u>
2764.5	39.7	109880

whence $n=19.7$ $v=21.1$ $u=20.7$

From these last figures it will be seen that n is less than $1/3$ of the corresponding x , so that it will be necessary to begin a light batter at some point above the 90 ft. section. As the shortage is about one foot, the best solution will be to start a batter of 1 in 10 at the 80 ft. point on the back face. These figures also show that the slope of the front face is so nearly uniform that further computation will be unnecessary for the 100ft. level, since the front batter which will be satisfactory at 90 ft., will be more than sufficiently close at 100ft. The resulting width on the 100 ft. level then, is 70.7 ft. To sum up the design we have: from El. 155 to El. 141, a rectangular section 10 ft. in width; from here the back continues vertical and the front batters at 5.62 in 10, to El. 125; the next batter of 6.52 in 10 runs to El. 115; the next, of 6.98 in 10, to El. 105; and the last to El. 55 at the bottom. At El. 75, 80 ft. below the top, the back batter of 1 in 10 begins and continues to the bottom.

For section 4.00, we obtain

from which		and the moments are	
1679.5	58719	1679.5	58719
949	40870	949	40870
145	10271	145	10271
2764.5	109880	2764.5	109880

whence $m = 7.7$ $n = 20.1$ $u = 20.1$

From these last figures it will be seen that n is less than $1/3$ of the corresponding u , so that it will be necessary to begin a light primer at some point above the 90 ft. section. At the anchor is about one foot, the least variation will be to start a batter of 1 in 10 at the 80 ft. point on the back face. These figures also show that the slope of the front face is so nearly uniform that further computation is unnecessary for the 100 ft. level, since the front batter will be satisfactory at 90 ft. and more than sufficiently close at 100 ft. The resulting on the 100 ft. level that $u = 70.7$ ft. we run on the design we have from El. 155 to El. 141, a rectangular section 10 ft. in 10 ft. from here the back continues vertical and the front batters at 0.52 in 10, to El. 125; the next batter of 0.52 in 10 runs to El. 110; the next of 0.58 in 10, to El. 105; and the last to El. 95 at the bottom. At El. 80 ft. below the top, the last batter of 1 in 10 begins and continues to the bottom.

Earth excavation.

Main dam		10290	cu. yds.	
Spillway				
Channel	47330			
Spillway site	<u>4170</u>	<u>51500</u>	"	"
Total		61700	"	"

Rock excavation.

Main dam		2635	"	"
Spillway		<u>105</u>	"	"
Total		2740	"	"

Concrete.

Main dam		20450	"	"
Spillway		<u>350</u>	"	"
Total		20800	"	"

Refill.

Main dam		9250	"	"
Spillway		<u>3920</u>	"	"
Total		13170	"	"

It is expected that these estimates will prove to be correct within considerably less than 10%, but it will be to the interest of the Contractor to satisfy himself on this point before entering his bid

Earth excavation.			
Main dam			10500 cu. yds.
Spillway			
Channel	4750		
Spillway side	1170		
Total			16170

Rock excavation.			
Main dam			2835
Spillway			105
Total			2940

Concrete.			
Main dam			20450
Spillway			350
Total			20800

Refill.			
Main dam			9250
Spillway			3920
Total			13170

It is expected that these estimates will prove to be correct within considerably less than 10%, but it will be to the interest of the Contractor to satisfy himself on this point before entering his bid.

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SPECIFICATIONS.

SECRETARY

11

11

SPECIFICATIONS.

1. Plans.

The plans referred to in these specifications are four in number entitled "Glendale Improvement Co., Concrete Dam at Glencoe Ill.", sheets one to four inclusive, dated May 15, 1906. They are general plans of the work showing its location and character, and will be supplemented from time to time as necessity shall arise, by working drawings to be furnished by the Engineer.

2. Character of site.

The nature and structure of the ground at the site are shown as completely as possible on the drawings, but any variation in character and location of material from that shown will not be considered a basis for claims on the part of the Contractor, since indications of tests are not warranted to be correct.

3. Description of work.

The dam is to be erected across what is known as the North Ravine, near the Village of Glencoe, about one-half mile from the Sheridan Road bridge over the main branch of the ravine. The dam is to be built wholly of concrete and ^{rubble} concrete founded throughout on rock as shown on the plans or as may be hereafter directed by the Engineer. Around the left or north end will be cut an overflow or spillway channel entering the main ravine through a branch below the dam. During the work this will be used as a diversion channel with its level at El. 145., and a temporary dam will be built about 1800 feet upstream which will turn its overflow into a temporary flume or other channel on the side of the main ravine and leading to the diversion channel. After the completion of the main dam, the diversion channel will be carried around the end of the spillway site until water can be let in behind the dam with the outlet pipe open,

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and in this way the spillway will be completed and the refilling done around it before the water will be high enough to flow over it. In order, however to provide against serious danger from flood, the north end of the dam shall always be kept lower than the south end to such an extent as may be directed by the engineer.

All work during its progress and upon its completion shall conform truly to the lines and grades to be given by the Engineer and shall be built in accordance with the plans and directions which may be given by him from time to time, subject to such changes as he may deem necessary during the prosecution of the work, and no materials furnished or work done in excess of the requirements of this contract as shown in the plans and specifications, will be paid for unless the same shall have been ordered by the Engineer under the provisions herein contained relating to extra work.

The Contractor shall furnish all material to be used in the construction, and all tools, implements, machinery, and labor necessary and convenient for putting into complete working order the work herein contracted for, within the time specified and with safety to life and property; and all work shall be done to the satisfaction of the Glendale Improvement Co., by its Board of Directors.

4. Methods and appliances.

The methods and appliances to be used by the Contractor on the work shall meet the approval of the Engineer as to their efficiency and appropriateness for securing the quality of work or the rate of progress required by the terms of this contract, and if at any time they do not, he may order the Contractor to increase their efficiency or improve their character, and the Contractor shall conform to such order; but the failure of the Engineer to give such order will not release the Contractor from his obligation to secure the quality of work and the rate of progress established in these specifications.

PROTECTIVE WORK.

5. Diversion.

Excavation of the diversion channel and construction of the temporary dam and runway shall be completed before work is begun on the main dam in the bed of the stream, and the same shall be done under the direction of the Engineer in the field and according to working plans to be furnished by him.

6. Responsibility for protection of work.

The Contractor shall erect all temporary dams, coffer dams, sheet piling, etc., and shall do all other work necessary for the control of the river and shall be responsible for all damage caused by the action of the water, whether from negligence or not. In case however, of damage caused by the inefficiency of the dam when the water shall have attained a height exceeding the official high-water mark, such damage shall be repaired by the Contractor under the direction of the Engineer as soon as possible, and the same shall be paid for according to the Engineer's estimate and upon his certificate of the satisfactory completion of the same. After the issuance of such a certificate, the Contractor shall resume the responsibility for damage as hereinbefore provided.

7. Prices

All work and material for purposes of protection from water, which have been ordered by the Engineer and approved by him, shall be paid for at the prices stipulated in this contract.

8. Pumping.

The Contractor shall do all pumping and draining necessary to keep the work free from water and shall take such steps as may be deemed necessary by the Engineer to maintain slopes and banks of excavations in proper shape. The cost of all appliances and work

connected with pumping and draining shall be included in the prices bid for the kinds of work which such pumping and draining is to protect.

9. Disposal of soil.

The soil to be removed from the site of any excavation shall be deposited as directed by the Engineer.

EARTH EXCAVATION.

10. Purpose.

Earth excavation is to be made for the preparation of the spaces into which masonry is to be built, for the uncovering of rock, and for any other work which may be ordered by the Engineer.

11. Definition.

Excavation of earth, hard-pan, and other materials including boulders, which do not require blasting for their removal, shall be classed as earth excavation and shall be paid for at the prices stipulated in this contract.

12. Measurements.

All measurements for earth excavation shall be made according to lines and slopes established by the Engineer from time to time. The Contractor shall conform to any modifications of the slopes as indicated on the plans, without extra compensation. The depth at which sloping excavation shall be abandoned and vertical trenches for masonry begun, shall depend upon the nature of the material to be excavated.

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13. Prices.

The prices stipulated in this contract for earth excavation shall include the work of clearing and grubbing the ground of all trees, stumps, bushes, and roots, of burning or otherwise disposing of the same, of bracing and sheeting and of supporting and maintaining all trenches and pits during and after excavation, of all pumping and draining, and of the disposal of all excavated materials.

REFILL AND EMBANKMENT.

14. Definition.

The work to be classed as refill and embankment shall consist of all earth and broken rock work necessary for refilling excavations and for making embankments.

15. Measurements.

Materials used for refill and embankment shall be measured according to the dimensions of the spaces to be filled and of the embankments in place.

16. Method of building.

All embankments shall start from well prepared bases, stepped on sloping ground, and all embankments and refills shall be carried up in horizontal layers not exceeding six inches in thickness, and shall be rolled with a heavy roller or rammed with a heavy rammer. Masonry or sheeting shall be kept at least two feet higher than adjoining embankments. Any portion of an embankment shall be so wet, when required, that water will stand upon the surface. The Contractor shall furnish satisfactory power for forcing water upon the embankment.

The first step in the process of the development of a new language is the selection of a set of basic words. These words are chosen from the vocabulary of the language to be developed, and are usually the most common and most useful words. The next step is to select a set of grammatical rules. These rules are chosen from the grammar of the language to be developed, and are usually the most common and most useful rules. The final step is to select a set of syntactic rules. These rules are chosen from the syntax of the language to be developed, and are usually the most common and most useful rules.

APPENDIX A

1. Definitions

The word "language" is defined as a system of communication. It is a system of communication because it is a system of symbols that are used to convey meaning. It is a system of communication because it is a system of symbols that are used to convey meaning. It is a system of communication because it is a system of symbols that are used to convey meaning.

2. Methodology

The methodology used in this study is a combination of qualitative and quantitative methods. The qualitative methods include interviews, focus groups, and content analysis. The quantitative methods include surveys, experiments, and statistical analysis. The combination of these methods allows for a comprehensive understanding of the research topic.

3. Method of selection

All participants were selected through a random sampling process. The random sampling process was used to ensure that the sample was representative of the population. The random sampling process was used to ensure that the sample was representative of the population. The random sampling process was used to ensure that the sample was representative of the population. The random sampling process was used to ensure that the sample was representative of the population. The random sampling process was used to ensure that the sample was representative of the population.

17. Material.

The quality of all material to be used for refill or embankment shall be approved by the Engineer, and any different materials to be used shall be brought to the embankment and mixed when required by him.

18. Borrow pits.

All borrow pits must be acceptable to the Engineer, and only such material as is acceptable for refill and embankment, will be paid for.

19. Prices.

The prices stipulated in the contract for refill and embankment shall include the cost of excavating and transporting materials from dumps or borrow pits; of supporting, draining, and maintaining excavations; of forcing water upon embankment or refill, and of doing all work as above specified.

20. Rock for refill and embankment.

All rock from the excavation ordered to be used for ^frefill or embankment shall be classed under refill and embankment and paid for at the prices stipulated in the contract.

ROCK EXCAVATION.

21. Definition.

Rock excavation is to include the excavation of such solid rock, boulders, or other material, as may require blasting for its removal, and the removal of masonry.

22. Measurement.

Rock excavation is to be measured to the lines determined

by the Engineer.

23. Explosives.

Explosives shall be used where directed by the Engineer and shall be of a kind and quality approved by him.

24. Foundations.

The rock surface for receiving the masonry shall be freed from all loose pieces and prepared as may be directed by the Engineer. The rock excavation is to be extended to such a depth and in such a manner as is shown on the plans or as may be ordered by the Engineer.

TIMBER.

25. Use.

Timber may be ordered used for platforms, flumes, channels, sheet piling, and for other permanent or temporary uses.

26. Quality.

Timber shall be of sound, straight-grained spruce or other wood equally acceptable to the Engineer, and shall be free from all shakes, loose knots, or other defects which would impair its strength or durability.

27. Measurements.

Timber work shall be measured and estimated in place. Round timber, used and accepted, shall be estimated by multiplying the useful length of the stick by the average of the end areas and taking 80% of the result ,

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28. Prices.

The prices bid for timber work shall cover all incidental expenses incurred for labor, tools, or materials used in placing or securing it. No payment shall be made to the Contractor for timber used for temporary purposes unless same has been left upon order of the Engineer and with his approval. All timber not left in work shall be removed by the Contractor at his own expense.

CONCRETE.

29. Cement.

The cement used shall be first class Portland of a reputable brand and shall conform in all respects to the specification for cement. It shall be stored so as to be fully protected from the weather and so as to admit of easy access for inspection and identification of each shipment. A sufficient quantity shall always be on hand to allow of a minimum of twelve days for inspection.

30. Sand.

The sand shall be clean and coarse or a mixture of fine and coarse grains with coarse grains predominating. It shall be free from clay, loam, sticks, organic matter, and other impurities. Screenings or crusher dust which have passed a 1/4 inch screen may be substituted for the whole or a part of the sand if the proportions be so altered as to give a dense mixture with the same relative volume of total aggregate.

31. Broken stone.

The broken stone shall consist of pieces of hard and durable rock such as limestone, trap, or granite. The dust shall be removed by a 1/4 inch screen unless the product of the crusher is delivered

The first part of the report is a summary of the work done during the year. It is followed by a detailed account of the work done in each of the four main sections of the report. The first section is a general survey of the work done in the year. The second section is a detailed account of the work done in the first section. The third section is a detailed account of the work done in the second section. The fourth section is a detailed account of the work done in the third section.

Summary

The first part of the report is a summary of the work done during the year.

The second part of the report is a detailed account of the work done in each of the four main sections of the report. The first section is a general survey of the work done in the year. The second section is a detailed account of the work done in the first section. The third section is a detailed account of the work done in the second section. The fourth section is a detailed account of the work done in the third section.

The third part of the report is a detailed account of the work done in each of the four main sections of the report.

The fourth part of the report is a detailed account of the work done in each of the four main sections of the report. The first section is a general survey of the work done in the year. The second section is a detailed account of the work done in the first section. The third section is a detailed account of the work done in the second section. The fourth section is a detailed account of the work done in the third section.

The fifth part of the report is a detailed account of the work done in each of the four main sections of the report.

The sixth part of the report is a detailed account of the work done in each of the four main sections of the report. The first section is a general survey of the work done in the year. The second section is a detailed account of the work done in the first section. The third section is a detailed account of the work done in the second section. The fourth section is a detailed account of the work done in the third section.

to the crusher so regularly as to permit of determining from samples the amount of dust which may then be allowed for in measuring the sand.

32. Rubble concrete.

All concrete in which large stones are placed by hand or by machinery, shall be classed as rubble concrete, and this should form about 40% of the entire mass of masonry. Large stones may be placed by derrick and should be fully covered with concrete. They should be joggled with crowbars so as to force out all air bubbles from beneath them.

33. Water.

The water shall be free from acids or strong alkalis.

34. Proportions.

The proportion of mortar in concrete shall be such as to slightly fill the voids of the aggregate. The Engineer shall, from time to time, make tests of the voids and shall give instructions as to the per cent of mortar of the specified composition, to be used. It may be said for the information of bidders that this per cent will be from 30% to 35%, as a rule.

35. Mixing .

The concrete shall be machine mixed in a machine which will permit of a precise and regular proportioning of all the materials and which will produce a mixture of uniform consistency and color with the stones and water thoroughly incorporated in the mortar.

1. The first part of the report is a summary of the work done during the year. It is a brief statement of the results of the work, and is intended to give a general idea of the progress made.

2. The second part of the report is a detailed account of the work done during the year. It is a full and complete statement of the work, and is intended to give a detailed account of the progress made.

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5. The fifth part of the report is a summary of the work done during the year. It is a brief statement of the results of the work, and is intended to give a general idea of the progress made.

36. Consistency.

The concrete shall be what is known as a wet mixture, so soft that it will run off the shovel unless handled quickly. If, however, the Engineer considers a drier mixture to be required on any particular part of the work, he may order the same to be used and such order shall be complied with by the Contractor.

37. Placing.

Concrete shall be conveyed to place in such a manner as to prevent any separation of the different ingredients, but in case such separation should inadvertently occur, the concrete shall in some way be remixed before placing. Concrete shall be placed, so far as possible in large masses and so that fresh lots shall not be laid upon old or dry surfaces. When it is laid in layers, each layer shall be thin enough to be incorporated with the preceding one. Old surfaces shall be cleaned of all dirt, scum, or laitance and shall be thoroughly wet before being covered with fresh concrete. Concrete shall be placed so soon after mixing as to be rammed or puddled to place as a plastic homogeneous mass. Any which has set before placing shall be rejected. Noticeable voids or pockets which may be exposed upon the removal of the forms shall be promptly filled with mortar of the consistency used in the concrete. Concrete laid in rock cuts shall fill the same completely up to the rock surface above which forms shall be used.

38. Surfaces.

Exposed surfaces shall be face cut with a thin flat tool while the mass is wet so that all large pieces of stone will be forced from the surface and a smooth face remain. Rubble shall not be laid within two feet of exposed faces. Except in freezing weather, forms shall be wet before placing concrete against them.

39. Freezing weather.

No concrete except that laid in large masses or in heavy walls, having faces whose appearance is of no consequence, shall be exposed to frost until dry. Materials employed in mass concrete in freezing weather shall contain no frost. Surfaces shall be protected from frost. Portions of surface concrete which have frozen shall be removed before laying fresh concrete upon them.

40. Forms.

The lumber for forms and their design shall be such as is best suited to the structure and to the surface required on the concrete. Forms shall be sufficiently tight to prevent the loss of mortar or cement, and they shall be thoroughly braced or tied together so that the pressure of the concrete or the movement of men or animals shall not throw them out of place. Forms shall be left in place until the Engineer may consider that the concrete has attained sufficient strength to resist any accidental or permanent strains which may come upon it, and permit of their removal. Forms shall always be thoroughly clean before being used.

41. Prices.

The price to be paid for concrete shall include the cost of all the ingredients delivered to the work and of mixing and laying the same as masonry, of all tools, machinery, and labor, and of setting in place all pipes, gate-valves, and other iron work called for by the design

CEMENT.

42. Packages.

Cement shall be packed in strong cloth or canvas sacks, or if in any danger from wet or damp, in paper lined barrels. Each package shall have stamped upon it the brand and the name of the maker. Packages received in a broken or damaged condition may be rejected or accepted as fractional packages.

43. Weight.

Four bags shall constitute a barrel in weight and the average weight of cement contained in a bag shall be not less than 94 lbs. net, or 376 lbs. per barrel. The weight of the separate packages shall be uniform.

44. Tests.

All tests shall be made in accordance with the methods proposed by the Committee on Uniform Tests of Cement, of the American Society of Civil Engineers, as amended January 20, 1904, with all subsequent amendments thereto.

45. Sampling.

Samples shall be taken at random from sound packages and the cement from each shall be tested separately

46. Requirements.

Cement failing to meet the requirements of the seven-day tests may be held to await the results of the twenty-eight-day tests before rejection. The following requirements shall be made the basis of acceptance or rejection of cement:

47. Specific gravity.

The specific gravity of the cement thoroughly dried at 212°F., shall be not less than 3.10 .

48. Fineness.

The residue on a No. 100 sieve shall be not more than 8.0% and on a No. 200 sieve not more than 25.0%.

49. Time of setting.

The cement shall develop initial set in not less than 30 minutes, and final set in not less than one hour nor more than ten hours.

50. Tensile strength.

Briquettes of one square inch cross section shall show at least the following strengths with no retrogression, within the time specified:

Neat cement.		Strength.
Age.		
24 hours in moist air		175 lbs.
7 days (1 day in air, 6 days in water)		500 "
28 " (1 " " " 27 " " ")		600 "
1:3 mortar.		
7 days (1 day in moist air, 6 days in water)		150 "
28 " (1 " " " 27 " " ")		200 "

51. Constancy of volume.

Pats of neat cement about three inches in diameter and one-half inch thick at the center, and tapering to a thin edge, shall remain firm and hard and shall show no signs of cracking or

17. Summary of results

The results of the study are summarized in Table 1.

Table 1. Summary of results.

18. Discussion

The results of the study are summarized in Table 1.

Table 1. Summary of results.

19. Time of collection

The results of the study are summarized in Table 1.

Table 1. Summary of results.

Table 1.

20. Summary of results

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Table 1. Summary of results.

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21. Summary of results

The results of the study are summarized in Table 1.

Table 1. Summary of results.

Table 1. Summary of results.

distortion under the following tests:

- (a) all pats are to remain 24 hours in moist air;
- (b) one pat is then to be left in moist air to the end of 28 days;
- (c) another is to be kept in water at 70 F. for 28 days,
- (d) a third is to be exposed in some convenient manner in an atmosphere of steam, above boiling water, in a loosely closed vessel for five hours.

52. Sulphuric acid and magnesia.

The cement shall contain not more than 1.75% of anhydrous sulphuric acid(SO_3), nor more than 4% of magnesia(MgO).

53. Iron and other metal work.

All metal work will be delivered on the ground at the expense of the Glendale Improvement Co., but the same is to be built into the work in strict accordance with the plans without any further compensation than the price stipulated to be paid per cubic yard of concrete

EXTRA WORK.

54. Definition.

All work uncalled for in these specifications but which may be ordered by the Engineer, shall be classed as extra work.

55. Measurements.

Extra work shall be measured by the Engineer and shall be paid for upon his certificate of the quantities of the same.

56. Prices.

Extra work shall be paid for at the unit prices stipulated in this contract for the various classes of work herein specified.

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57. Formal claims.

No claims for extra work will be allowed unless made in writing previous to its performance and signed by both parties to this contract or their authorized representatives.

GENERAL CLAUSES.

58. Imperfect work.

Imperfect work or materials, or work or materials which may become damaged from any cause before its acceptance, shall be properly replaced to the satisfaction of the Engineer.

59. Foremen.

Foremen employed by the Contractor shall be skilled in the kinds of work for which they are employed.

60. Authority of Engineer.

Instructions from the Engineer regarding the character or quality of the work, shall be obeyed by the Contractor and his representatives.

61. Lines and grades.

All lines and grades are to be given by the Engineer who may alter them from time to time, provided such alterations do not materially affect the measurements. The Contractor shall preserve all stakes and give such assistance as is necessary to the Engineer in establishing benches and plugs and in making measurements.

62. Ambiguity in terms.

In case of disagreement as to the meaning of the terms of this contract or these specifications or as to the manner of their

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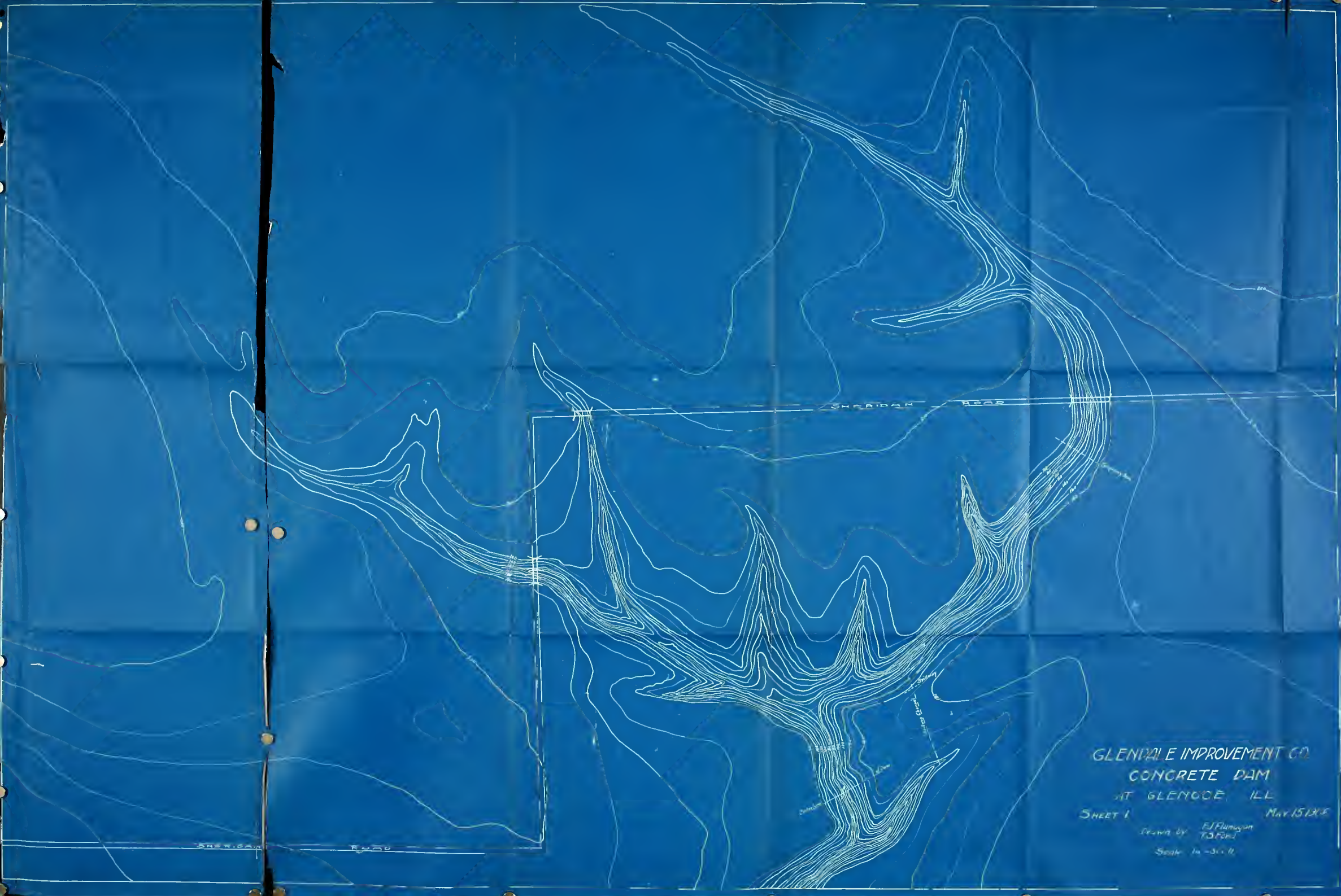
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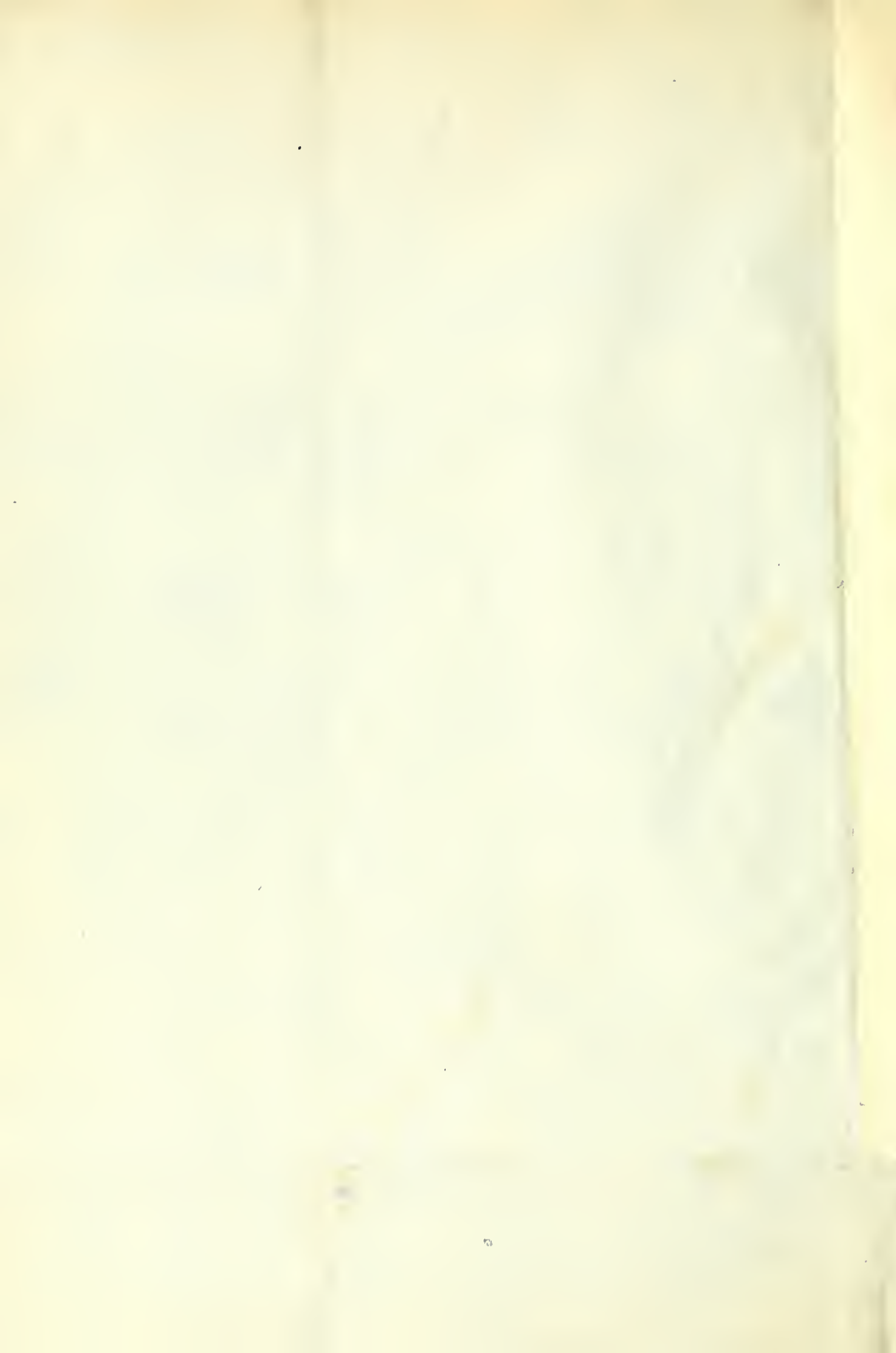
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this contract or these specifications or as to the manner of their



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CONCRETE DAM
AT GLENDOE, ILL.
SHEET 1
Drawn by E.J. Flanagan
T.O. Ford
Scale 1" = 300' H.

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GLENDALE IMPROVEMENT CO.
 CONCRETE DAM
 AT GLENCOE ILL.

SHEET 2

May 15, 1906

Drawn by
 E. J. Flanagan
 T. S. Ford

Section 25 1/2 Street

Hard Shale

Clay
 &
 Soft Shale

Section on Center Line of Roadway

Hard Shale

Clay
 &
 Soft Shale

Sec. A-B Turn Spillway Channel

Clay
 &
 Soft Shale

Hard Shale

Bottom of Spillway Channel

Grade 145 ft

Hard Shale

Clay
 &
 Soft Shale

Section of Spillway Channel

Sta 4.00

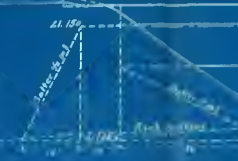
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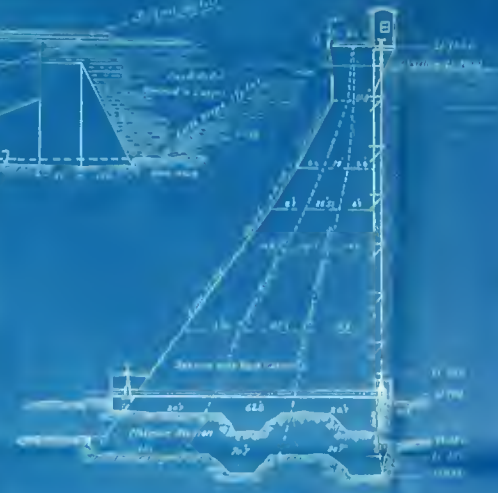
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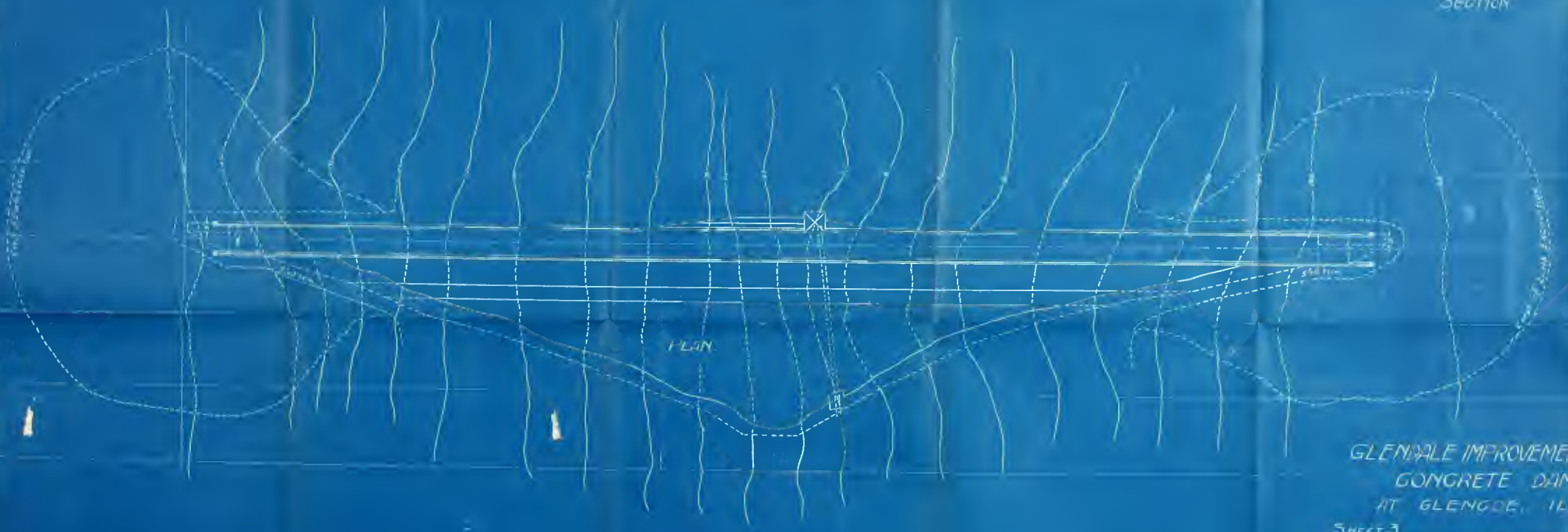


HALF ELEVATION

HALF LONGITUDINAL SECTION



SECTION



PLAN

GLENDALE IMPROVEMENT CO
 CONCRETE DAM
 AT GLENDALE, ILL.
 SHEET 3
 Drawn by E.J. Thompson
 T.O. Ford
 Scale 3"=50'
 May 15, 1906

1e 1/4" = 1'

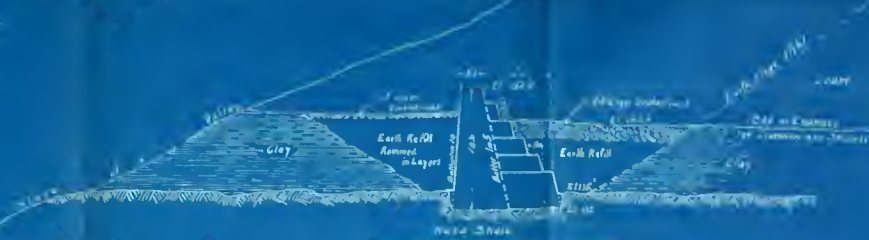
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AT GLENCOE, I

SHEET 4

Drawn by F.J. Flanagan
T.S. Ford



LONGITUDINAL SECTION IN OPEN CUT

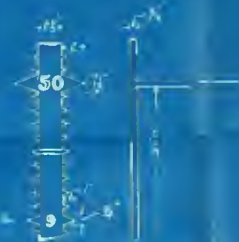


FINISHED CROSS SECTION

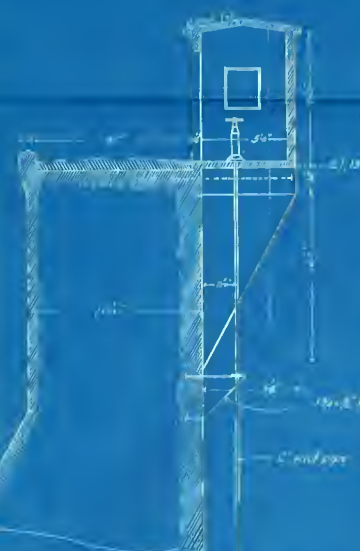
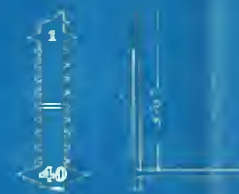


PLAN

SPILLWAY
Grade 1750



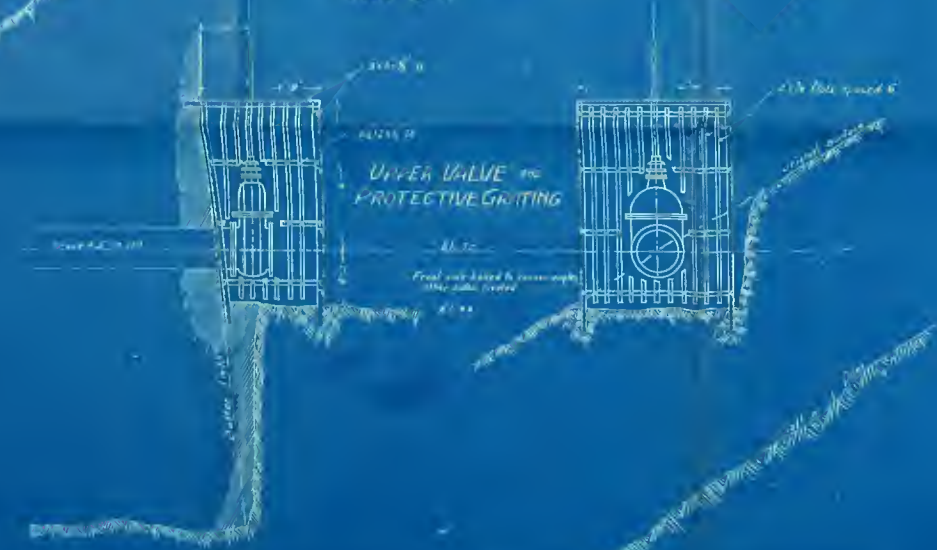
DETAIL - GRADE MARKS



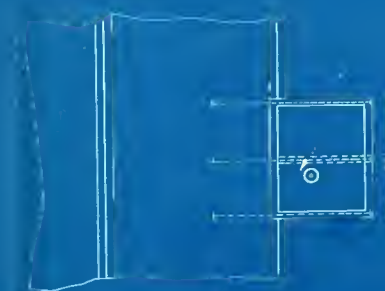
DETAILS OF GATE CHAMBER (UPPER)
Scale 1/2" = 1'



LOWER GATE CHAMBER
20' RENSSELAER HP VALVE
Scale 1/2" = 1'



UPPER VALVE AND PROTECTIVE GRATING
Scale 1/2" = 1'



GLENDALE IMPROVEMENT CO.
CONCRETE DAM
AT GLENGOE, ILL.

SHEET 4

Drawn by J. J. Flanagan
T. J. Ford

MAY 15, 1906

